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THE PHYSICAL CHEMISTRY OF SEGER CONES

BY

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THE PHYSICAL CHEMISTRY OF SEGER CONES

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No doubt every member of this Society has used Seger cones for the measurement of heat effect. Furthermore, a number of excellent papers on this subject have been given before this Society in past years and these have been quite actively discussed. There is, therefore, little need for my going into the facts regarding pyrometric cones; but there are certain familiar properties of Seger cones which seem not to have been clearly explained on the basis of physico-chemical laws. It seemed that a brief treatment of these from the standpoint of the laboratory worker in silicates might be of interest.

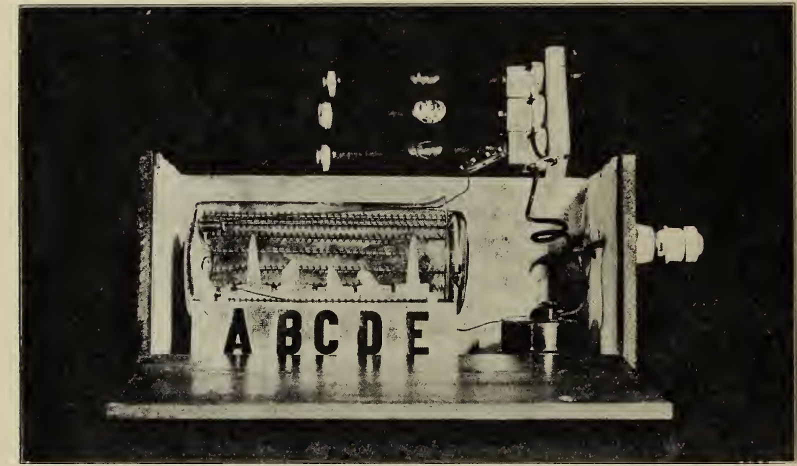

Fig. 1. Lecture experiment showing control exercised by the eutectic melting point upon the indications of pyrometric cones.

I can best introduce the subject by a simple lecture experiment. I have here five cones, made up of mixtures of sodium and potassium nitrates. Cone A is 100 percent sodium nitrate; cone B contains 25 molecular percent potassium nitrate; cone C contains

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50 percent, and cone D 75 percent potassium nitrate and E is pure potassium nitrate.

On the basis of proportionality between fusing temperature and composition, we should expect cone A to go down at the melting point of sodium nitrate, namely 308°, followed by B, C, and D in order, and ending with cone E at the melting point of potassium nitrate, which is 337°. As a matter of fact cone C starts first. But what I want you to note especially is that B and D are coming down at the same time.[1]

In Figure 2 are plotted the compositions and melting temperatures of the cones used in the experiment. Potassium nitrate above 337° is of course a liquid; as it is cooled down it solidifies at that temperature all at once. If we add a little sodium nitrate to it, it will begin to freeze at a lower temperature, just as water begins to freeze at a lower temperature when salt is dissolved in it. The continued addition of sodium nitrate to potassium nitrate continues the lowering of the freezing point, down to a point where further additions will cause the mixture to begin freezing at a *higher* temperature. A familiar analogy is the case of salt and ice. If we add salt to ice in increasing amounts, we get down to a certain minimum temperature, and further additions will give a higher temperature. This composition of minimum freezing point is known as the eutectic composition. In the case of these two nitrates it happens to be very nearly 50 molecular percent. In general, it might lie anywhere between the two pure substances. I have gone into some detail in this explanation, because I believe these facts are so fundamental that they cannot be repeated too often.

Any mixture except the eutectic will contain, as you can readily see, a certain proportion of this eutectic mixture, together with an excess of one of the components. For instance, the mixture of 25 percent of component A and 75 percent of component B will contain 50 percent of the eutectic mixture and 50 percent of excess of B. Therefore, when the temperature reaches the eutectic melting temperature, 50 percent of the mixture will melt. Any cone made up of a mixture of these two components will consist, above the eutectic temperature, of a mixture of solid and liquid, the liquid being fairly thin; hence all the cones between A and E will

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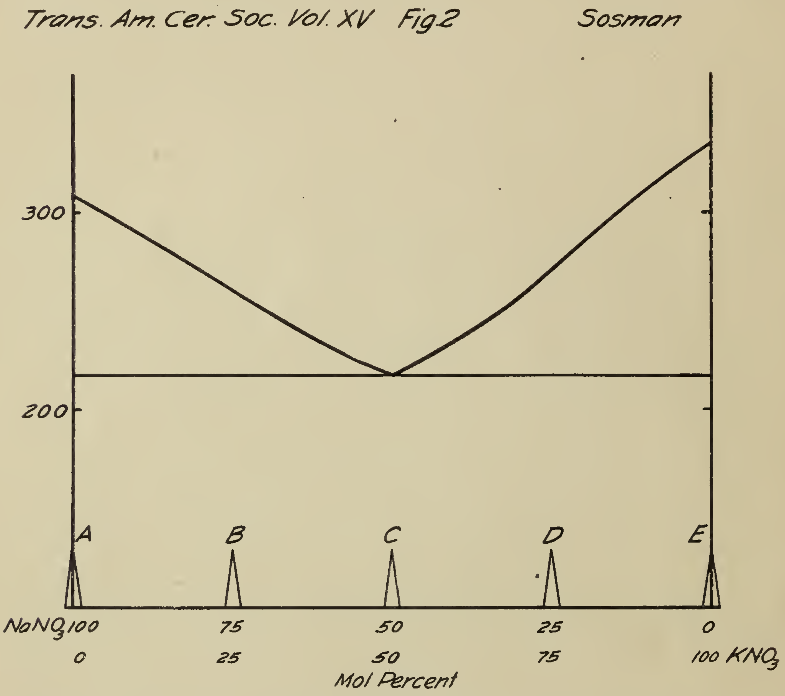
[1] See Figure 1. The furnace used for this experiment consists of a cylindrical steel cage, open in front, made of two metal rings into which rods are screwed. Glass tubes are slipped over the rods, and a helix of about 40 feet of No. 20 nichrome resistance wire is threaded over the glass tubes. The cones are cast in an iron mold, and stand on a shelf of asbestos board. The furnace is inclosed by two glass beakers, one slipping inside of the other.



Fusion curve of the system $NaNO_3-KNO_3$. Recalculated to molecular percentages from data of Carveth.[2]

come down at once, because a thin liquid, even though it contains a solid in suspension, cannot stand up in the form of a cone.

That is the fundamental principle which I want to bring out. We will apply it first to the series of cones numbered 28 to 42. Here we have a series whose relations are easy to represent, because it contains only two components, silica and alumina. This series has been investigated by Shepherd and Rankin at the Geophysical Laboratory.[3]

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[2] J. Physic. Chem. II, 209-228, (1898). Later investigation by Hissink, in Z. physik. Chem. XXXII, 537-563, (1900), shows that this is not a simple eutectic system as stated by Carveth, but that each of the component salts carries the other in solid solution to a limited extent. This fact does not change the form of the fusion curve, however.

Quartz is the form of silica used in making up cones 28 to 42. At temperatures above 1600° quartz changes rapidly into cristobalite, which melts at about 1625°.[4] Its rate of melting at this temperature is, however, very slow.

Alumina enters the cones in the form of kaolinite, $Al_2O_3.2SiO_2.2H_2O$ and, in the higher numbers, pure aluminum hydroxide. Kaolinite is not a stable compound at high temperatures, even after loss of water, and appears to decompose into aluminum silicate (Al_2SiO_5) and free silica. The only compound that occurs on the fusion curve is sillimanite, Al_2SiO_5. This compound melts at 1816°. Pure alumina melts at 2050°.[5]

None of these three substances, cristobalite, sillimanite, and alumina, contains the others in solid solution to any considerable extent. A eutectic mixture forms between cristobalite and sillimanite, and another between sillimanite and alumina. We have here, then, two simple binary systems side by side; each may be expected to behave just as the series of little nitrate cones is behaving.

The curve of Shepherd and Rankin is shown in Figure 3. On the same diagram are shown the compositions of cones 28 to 42, as well as the nominal and the experimentally determined temperatures at which the cones fall.

On the basis of what we have seen happening in the case of the nitrate cones, we should expect that the cones which represent pure compounds should stand up indefinitely at temperatures below their melting points. All the others should come down at or near the temperature of the eutectic, excepting those which lie so close to the pure compound that the excess component forms a rigid skeleton which is not pulled down by the flowing eutectic. Thus numbers 28 to 36 should come down near 1600°, 38 and probably 37 above 1800°, 39 to 41 at about 1800°, and 42 at 2050°.

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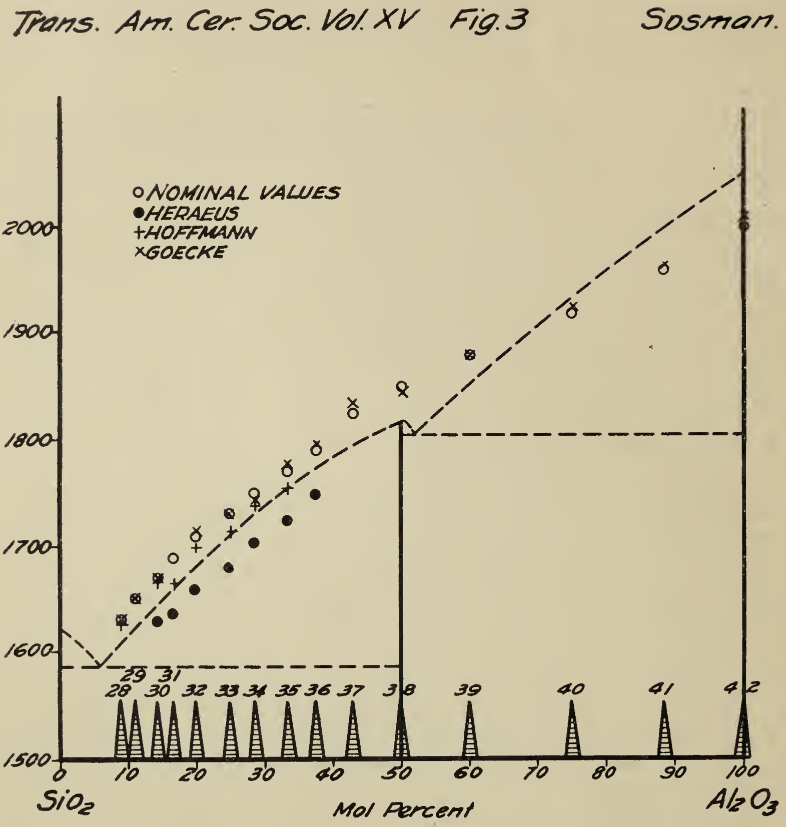
[3] *Am. J. Sci.* 28, 293–333. 1909.

[4] C. N. Fenner. *Am. J. Sci.* 1913.

[5] Kanolt. *J. Wash. Acad. Sci.* 3, 315–318. 1913.



Composition-temperature diagram for the system SiO_2—Al_2O_3, according to Shepherd and Rankin,[6] showing the composition of cones 28—42.

The published determinations[7] of the indicating temperatures of these cones show that they fall near, and at most not far below, the curve of Shepherd and Rankin. These determinations were all made in laboratory furnaces, at fairly rapid rates of heating.

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[6] Am. J. Sci. XXVII, 302, (1909.)

[7] Heraeus and Haagn. *Zs. angew. Chem.* 18, 49–53. 1905. Hoffman and Meissner. *Tonind. Ztg.* 33, 1577–1581. 1909. *Zs. Instr.* 30, 179–189. 1910. Goecke. *Metallurgie.* 8, 667–676. 1911. These experiments have been corrected to the uniform scale on which the palladium melting point is 1549°, and platinum 1755°.

But Kanolt reports that, at slower rates, the temperatures indicated by these cones fall 40° to 70° below the nominal.[8]

I have made a simple test of the effect of slow heating upon a number of high temperature cones which Dr. Kanolt had on hand at the Bureau of Standards. Number 28 (Orton and Berlin), 29 (Orton), 30 (Orton and Berlin), 31 (Orton) and 33 and 34 (Berlin) were all heated together in a covered crucible in a Fletcher gas furnace. The temperature, measured with a platinum-platinrhodium thermoelement, rose for one hour and then was held as steady as possible for five hours. The average temperature during this time was 1616°, which is below the nominal temperature for No. 28. At the end of five hours all the cones were down except 33 and 34; 33 was about one-fourth down, and 34 had started to bend. Microscopic examination of No. 34[9] showed that it consisted, after cooling, of a felted network of sillimanite crystals, with about an equal quantity of isotropic material of refractive index between 1.47 and 1.495. The index of this latter material apparently lies between that of pure fused silica and that of cristobalite, and it is perhaps a submicroscopic mixture of these.

We have seen, therefore, that if given sufficient time, these cones tend to reproduce the behavior of our experimental nitrate cones. What then are the causes for the delay in their response to the temperature?

The first and most important cause is the fact that the silicate cones are not homogeneous, in the chemical sense. Cones 28 to 41 are made up of mixtures of quartz and kaolin, or kaolin and alumina. The quartz must invert into cristobalite, and the kaolin must decompose into cristobalite and sillimanite. In cones 28 to 37, sillimanite and excess cristobalite must then melt together into the eutectic; in cones 38 to 41, cristobalite and excess alumina must unite to form more sillimanite, and this again melts down with excess alumina into a eutectic. The cones as made up have therefore not the same physical constitution that they would have if first melted and then made up out of the melted material.

The first cause of delay, therefore, is the chemical reaction taking place between these solids to bring them into their final condition of equilibrium. They do combine, however, in the solid state, and there is considerably more diffusion and reaction in the solid state than is ordinarily supposed. This is well shown by a simple lecture experiment. (Two coarsely crystalline organic solids, guaiacol and salol, were mixed in a test tube, and immediately began to liquefy; in a few minutes they formed a clear liquid.)[10]

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[8] Burgess. "Measurement of High Temperatures," p. 376. 1912.

[9] Microscopic examinations by Dr. H. E. Merwin.

Guaiacol melts at 28° and salol at 42°. Both of these solids will therefore remain crystalline indefinitely at the ordinary temperature of the room, about 20°. But their eutectic mixture melts considerably below room temperature. If the solids are mixed, therefore, they are not in equilibrium, and the liquid eutectic immediately begins to form at every point of contact between the solid crystals.

In the same way cristobalite and sillimanite should liquefy one another, even though the temperature is below the melting points of both components, provided only that the temperature is above the melting point of the eutectic. But the fact that this interaction must first take place constitutes, as I have said before, the first reason for delay in the response of the cone to the high temperature.

The second cause for delay in cones is the very slow time-rate of melting of silica and the alkali feldspars. Silica and the highly silicic feldspars are peculiar in this respect, that they can be heated above their melting points and still remain crystalline.

This is not a stable condition, that is, not a "superheated" condition. We have always believed that crystals cannot be superheated, in the same sense in which a liquid can be undercooled, and this remains true, because during all the time while these substances are above their melting points, melting is going on. In the course of half an hour, at a temperature some degrees above its melting point, orthoclase for instance will melt to a certain extent; in the course of another half hour it will melt still further, and finally it will become entirely liquid.

A third reason is the very viscous character of the liquid which is formed. Cristobalite above its melting point forms a very viscous liquid, and the same is true of the alkali feldspars. They will, however, flow when once melted. Even pitch, as you know, will flow gradually, although under a sudden blow it behaves like a brittle solid.

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[10] This experiment was suggested by Dr. F. E. Wright.

We come now to the cones numbered 5 to 27. These cones are in effect made up by taking as a basis cone 28, which is practically the eutectic of aluminum silicate and silica, and adding thereto varying quantities of a mixture containing 30 molecular per cent of calcium silicate and 70 molecular percent of potassium silicate. In actual practice, they are made up of quartz, kaolin, orthoclase, and marble or calcium carbonate. These cones 5 to 27 belong therefore in the four-component system: SiO_2-Al_2O_3-CaO-K_2O. It is impossible to represent graphically the compositions in a four-component system, together with the temperature, although composition alone may be represented by points within a tetrahedron.

In order to bring out clearly the composition and behavior of these cones 5 to 27, I have tried to make some simplification, in the first place by neglecting the component which is least active, namely, silica. We will consider the *excess* of silica as being a neutral substance which forms the body of the cone.[11] We will take as the other three substances:

1. Calcium silicate, $CaSiO_3$; this is the most highly silicic compound of CaO and SiO_2. It is not present initially in the form of $CaSiO_3$, but in the form of calcium carbonate and silica; but it is an easily formed compound and melts sharply.

2. Aluminum silicate, Al_2SiO_5, the only compound of Al_2O_3 and SiO_2 which is stable at high temperatures. It is present as an integral part of the kaolin used in making the cones. Like calcium silicate, it melts sharply.

3. Orthoclase, $KAlSi_3O_8$ or $K_2SiO_3.Al_2SiO_5.4SiO_2$; we take this as the third component in preference to K_2SiO_3 because orthoclase is a stable compound and is one of the actual constituents of which the cones are made. Even though it is rather a slow melting substance, it melts perhaps faster than silica and at a fairly low temperature.

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[11] Thin sections of two cones, numbers 12 and 15, which had been heated in a porcelain kiln until No. 12 fell, were made in the Geophysical Laboratory some years ago. Both consisted of glass containing considerable amounts of fragmental quartz, apparently almost unacted upon. The glass contained also a small amount of some very minute crystals which had formed on cooling, perhaps Al_2SiO_5.

In order to understand clearly the principles underlying the behavior of such a three-component system, it will be well to review briefly the relations in some simpler systems.

As you well know, the relations of composition and temperature in such a system can be represented by plotting the various mixtures of the three components as points within an equilateral triangle, and the temperatures upward at right angles to the plane of the triangle. A space model can be constructed in this way which will represent the transformation points and melting points of all possible mixtures.

The simplest three-component system is one in which no compounds or solid solutions are formed between the components. There is one mixture of the three which melts completely at a lower temperature than any other mixture, and so forms a "ternary eutectic." A simple system of this kind is illustrated in Figure 4.[12]

The next three-component system in order of complication will be one in which two of the three components form a compound, but no solid solutions occur. A maximum point in the curve of melting temperatures occurs at the composition of the compound, and eutectic mixtures form between the compound and each of its two components. Addition of the third component to the pure compound lowers the melting-point of the latter, and a eutectic mixture occurs between compound and third component. In effect then, this system can be resolved, in its simplest case, into two simple three-component systems side by side, each resembling Figure 4 and having a ternary eutectic. The best example of such a system is that shown in Figure 5.

If, in a system of the type of Figure 5, the third component (the one which forms no compound) be supposed to enter into solid solution in the compound to a limited extent, and conversely, the compound enters into solid solution with the third component, we would have a diagram similar in form to Figure 5 with the possibility again of two ternary eutectics.

Unfortunately, experimental data on the system: orthoclase-$CaSiO_3$-Al_2SiO_5 are very scarce. The two-component system $CaSiO_3$-Al_2SiO_5, however, may be considered a cross-section of the

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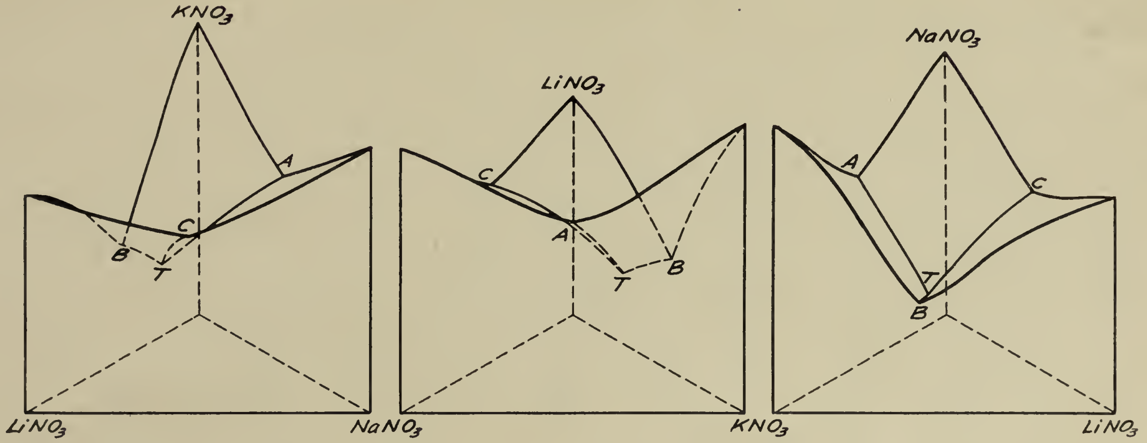
[12] These systems were shown in the form of plaster models.

Trans. Am. Cer. Soc. Vol. XV Fig. 4 Sosman



Three views of the composition-temperature space model for the system $KNO_3 - NaNO_3 - LiNO_3$. Recalculated to molecular percentages from data of Carveth.[13]

KNO_3	m. p. 337°
$NaNO_3$	m. p. 308°
$LiNO_3$	m. p. 253°

A	Eutectic KNO_3 and $NaNO_3$	m. p. 218°
B	Eutectic KNO_3 and $LiNO_3$	m. p. 129°
C	Eutectic $NaNO_3$ and $LiNO_3$	m. p. 204°
T	Ternary eutectic	m. p. 119°

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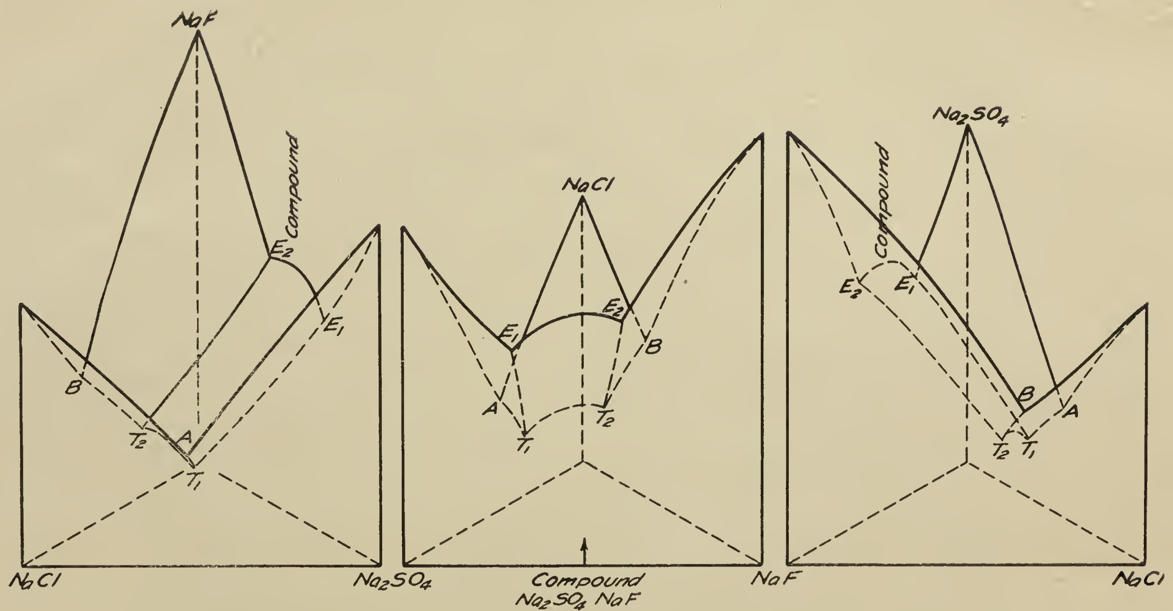
[13] See note to Figure 2.

Trans. Am. Cer. Soc. Vol. XV Fig. 5 Sosman



Three views of the composition-temperature space model for the system $NaCl-NaF-Na_2SO_4$. Data of A Wolters.[14]

$NaCl$ .... m. p. 797°
NaF .... m. p. 986°
Na_2SO_4 .... m. p. 881°
Compound $Na_2SO_4.NaF$ .... m. p. 781°
A Eutectic: NaCl and Na_2SO_4 .... m. p. 624°
B Eutectic: NaCl and NaF .... m. p. 674°
E_1 Eutectic: Compound and Na_2SO_4 m. p. 743°
E_2 Eutectic: Compound and NaF ... m. p. 773°

T_1 Ternary eutectic; compound, NaCl and Na_2SO_4 .... m. p. 594°
T_2 Ternary eutectic; compound, NaCl and NaF .... m. p. 620°
Maximum in boundary curve T_1 T_2 (eutectic of compound and NaCl) .... m. p. 624°

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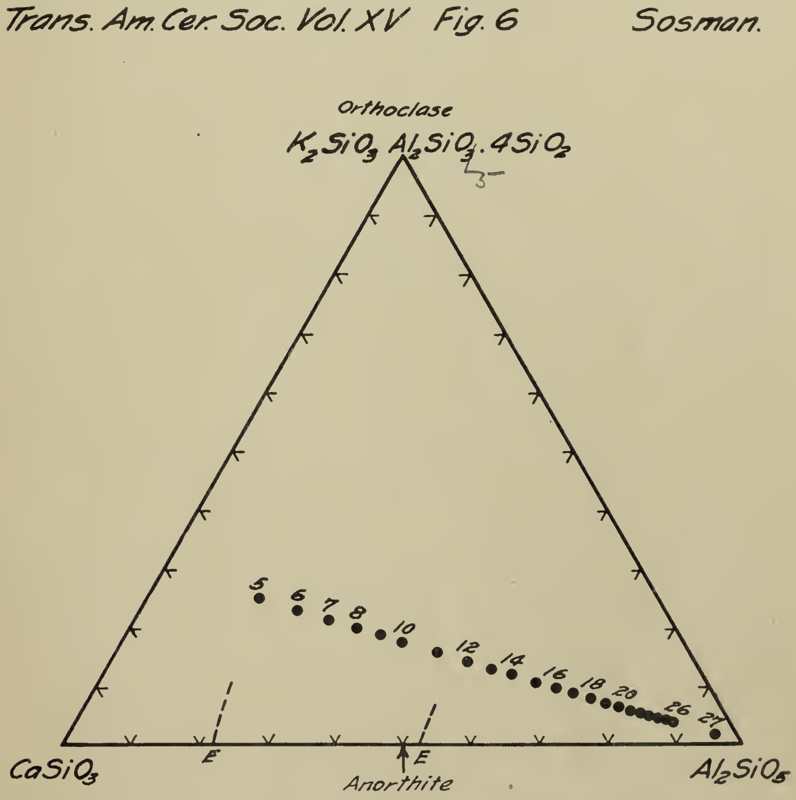
[14] N. Jahrb. Min. (1910). Beilbd. XXX, 55-96.

system CaO-Al_2O_3-SiO_2, so thoroughly studied by Shepherd and Rankin.[15] In this system there occurs the one compound, anorthite, $CaSiO_3.Al_2SiO_5$, with a binary eutectic on either side. For the rest of the diagram, the evidence of the composition of natural minerals and occasional scraps of experimental evidence all point to the form of fusion diagram described in the preceding paragraph, as being applicable to the system orthoclase-$CaSiO_3$-Al_2SiO_5.

In Figure 6 are shown the compositions of cones 5 to 27 as far as the bases are concerned, omitting excess silica. Since the



Basal composition of cones 5 to 27, disregarding excess of silica. E, eutectic.

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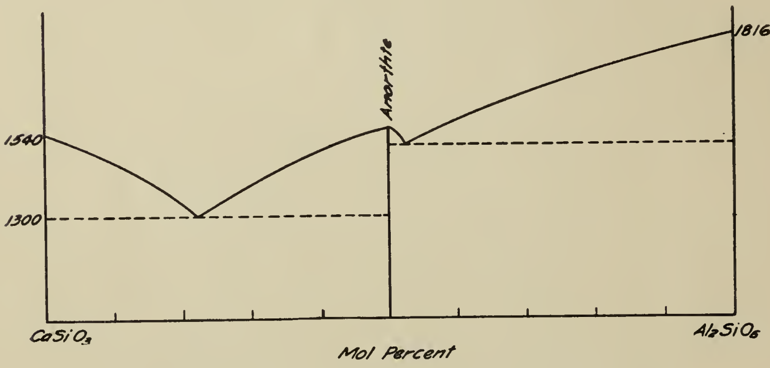
[15] *J. Ind. Eng. Chem.* 3, 211-227. 1911.

proportion of potash to lime is constant, they lie on a straight line across the diagram. The letters E E mark the positions of the eutectics of the two-component system $CaSiO_3$-Al_2SiO_5, and the dotted lines show the probable course of the boundary curves into the three-component system. Figure 7 shows the fusion curve for the two-component system $CaSiO_3$-Al_2SiO_5.[16]

If the properties of these cones are in fact fundamentally controlled by the properties of the three component system orthoclase-$CaSiO_3$-Al_2SiO_5, and if this system has a fusion surface like that indicated by Figures 5–7, then it is possible to make certain predictions about these cones. In the first place, the low and well marked eutectic between anorthite and calcium silicate indicates a correspondingly low and well marked ternary eutectic into which orthoclase and orthoclase-bearing anorthite will enter. Cones 5 to 8 should therefore be easily influenced by the rate of heating and should show strongly the tendency to come down in a group.

Trans. Am. Cer. Soc. Vol XV Fig 7 Sosman



Form of fusion diagram for the system $CaSiO_3-Al_2\ SiO_5$.

Cone 10 lies on the line joining anorthite and orthoclase; 9 and 10 should therefore show less markedly the effects of slow heating.

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[16] The system $CaSiO_3$-Al_2SiO_5 is not, in the strictest sense, a two-component system, since Al_2O_3 appears as a phase near the Al_2SiO_5 side, due to decomposition. This is a complication of secondary importance, however, in our present considerations.

The anorthite-sillimanite eutectic is quite near anorthite and will influence 11 and 12 in a manner similar to the effect exercised on 5 to 8 by the lower eutectic. The increasing quantity of high melting and skeleton-building sillimanite in the higher cones will cause them to show these influences less and less, until beyond 18 the increasing amount of the sillimanite-cristobalite eutectic requires to be taken into account. These higher cones will appear from another point of view in a later paragraph.

Recorded experience with cones confirms the above predictions in large measure. Seger himself recognized that the lower silicate-alumina cones came too close together: "5, 6 and 7 do not differ much in regard to melting point, ... but I did not desire to do away with the cones 5, 6 and 7 because their numbers correspond to the acidity."[17] Professor Orton said[18] in the discussion of Mr. Geijsbeek's paper in 1904: "I find it almost impossible to make cones 4, 5, 6, 7 and 8 so that one will not sometimes overtake the other." He stated also that he had found the German No. 5 to fall occasionally before No. 4.[19] These instances could no doubt be multiplied from the experience of any user of these cones.

The introduction in Germany of the new "a" series of borosilicate cones by Simonis in 1908 has probably obviated these difficulties to a considerable extent, since 6a, the highest number of the new series, approximately replaces numbers 4, 5 and 6. But the introduction of three additional components (soda, magnesia, and boric acid) complicates the question so much that I have not ventured to discuss their chemical relationships.

Taking up, further, the cones above No. 8, we find numerous experiments which bear out our general predictions. Loeser,[20] for instance, after studying the behavior of the entire series up to about No. 19, states that the groups which show the greatest irregularity are numbers 018 to 012, 1 to 7, and 11 to 12. The effect of slow firing in lowering the falling-temperatures of all the silicate-alumina cones in most common use (comprising numbers

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[17] *Gesammelte Schriften*, p. 194.

[18] *Amer. Ceramic Soc. Trans.* 6, 99. 1904.

[19] No. 4 occupies the same position as No. 5 in Figure 6. The ratio of bases is the same in both, but No. 4 contains less excess silica.

[20] *Sprechsaal.* 40, 499–501. 1907.

4 to 20) has been a matter of frequent observation. Zimmer[21] reported that 1 to 9 gave temperatures 25° to 30° lower in a slow fired biscuit kiln than in a smaller trial kiln. Geijsbeek's experiments[22] showed lowerings of 75° to 85° below the nominal values, in long burns with cones 1 to 7. Much more extensive tests were made by Hoffmann[23] covering cones 4 to 35 in laboratory furnaces, and 7 to 17 in commercial kilns. The long continued heating under kiln conditions produced lowerings of from 40° to 110° below the laboratory furnace values. Excellent examples of the control exercised by the low-melting eutectic may be found in the elaborate experiments of Rieke.[24] I will quote one which is of especial interest: "In another burn cones 6 to 10 were heated for some time at 1160° to 1180°. After three-quarters of an hour cone 6 began to bend, and was down after one and one-half hours. After two and one-quarter hours cone 7 followed, and after two and one-half hours, cone 8. After 5 and one-half hours cone 9 was somewhat bent, and superficially glazed, while cone 10 still stood quite erect." It will be remembered that 10 lies on the line between the pure compounds anorthite and orthoclase. The effect of the eutectic in pulling the cones down one after another at a constant temperature is here quite evident.

The investigations of cones 19 to 26 by Simonis in 1907[25] showed that these fall so near together in their temperature indications (1530° to 1566°) that several of them could well be omitted. Numbers 21 to 25 were therefore dropped from the list and are no longer made. One reason for their close approximation in fusing points is evident from the diagram of Figure 6, namely, that the proportion of aluminum silicate varies very little from cone to cone.

These cones, furthermore, lie near the boundary curve for cristobalite, aluminum silicate, and calcium silicate in the three-component system SiO_2-$CaSiO_3$-Al_2SiO_5. In other words, the cristobalite-sillimanite eutectic of Figure 3, lowered by the addition of calcium silicate, probably exercises greater control over the cones at this end of the series than do the eutectics of Figure 6.

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[21] *Amer. Ceramic Soc. Trans.* 1, 23–38. 1899.

[22] *Amer. Ceramic Soc. Trans.* 6, 94–99, 1904.

[23] *Sprechsaal.* 44, 143–144. 1911.

[24] *Sprechsaal.* 44, 726–729, 741–744. 1911.

[25] *Sprechsaal.* 40, 71–72. 1907. *Tonind. Ztg.* 31, 146–148, 1907.

What I have said is not intended in any way to decry the usefulness of Seger cones. Their use by hundreds of plants over a period of twenty-five years, and their continued use today side by side with thermoelectric and optical pyrometers, is evidence enough to the man on the outside that Seger cones are practically indispensable to the clay-working industries. But what I have said may serve to emphasize the statement that cones do not measure *temperatures*. They are indicators of heat effects, and as such are very efficient tests for the control of an industrial process. Their use may also be extended to other tests which are in nature of the control of a process, such for instance as the comparison of the softening temperatures of coal ash, where the relative fusibility of different ashes, and not the exact temperature of incipient or complete fusion of a given ash, is the information desired.

Efforts and suggestions have been frequently made with the object of causing the cones to come somewhat nearer to measuring temperature, independent of time and other variables. A recent patent issued to the laboratory of Seger and Cramer[26] covers the use of hollow cones to give more rapid action. Another[27] covers the procedure of first fusing the materials, and then making the cones out of the fused mixtures, in order to do away with the delay in action incident to preliminary reactions among the constituents. But neither of these expedients removes the cone from the influence of its lowest melting eutectic; indeed, the second would place it more under the control of the eutectic than before. Furthermore, it would seem that as a test for controlling a process the slow-acting cone serves a purpose that the quick-acting cone does not, in giving warning that the final stage of a desired heat effect is being approached, and in allowing time for the fire to be regulated accordingly.[28]

If it is desired to obtain a sharp indication of a given temperature, independent of the rate of heating, the fundamental principle is evidently to use only pure compounds or pure eutectics. In spite of numerous statements in silicate literature to the contrary, there are numerous compounds and eutectics among the silicates which melt at perfectly definite temperatures, and melt promptly when those temperatures are attained. Furthermore, it is not at all necessary to resort to the slow-melting and very viscous alkali feldspars. A number of these sharp melting compounds are in common use in the Geophysical Laboratory for calibration of thermoelements and occasionally for the direct indication of temperatures. The principal objection to their general use is the necessity of employing very pure chemicals, and of keeping them pure when the mixtures are made. Further research will reveal an increasing number of such compounds and mixtures, and will no doubt show the way toward their application industrially for the measurement of temperature.

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[26] German patent 197450, June 1, 1907.

[27] German patent 197698, June 1, 1907.

[28] Discussion in *Trans. Amer. Ceramic Soc.* 8, 163. 1906.

The Chairman: Gentlemen, I presume there are quite a number of you who want to ask questions or discuss in some way this exceedingly valuable paper. We will have to get to it at once and not lose any time.

Mr. Purdy: It is beyond the depth of most of us; I think all we can do is to congratulate the author on his fine presentation of the subject and thank him, and I make this motion.

(Motion seconded and adopted.)

Mr. Chairman: In the name of the Society, Dr. Sosman, we thank you for this paper.

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